LIDAR AND SUN PHOTOMETER FOR AEROSOL INVESTIGATION IN TIMISOARA

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REZUMAT. Scopul acestui studiu este de a combina două metode de teledetecţie pentru analiza aerosolilor. Prin combinarea diferitelor metode mai multe informatii privind tipul de aerosoli, sursa si alte caracteristici. Studiul aerosolilor atmosferici a dobândit un mare interes în ultimii ani, datorită probelor care dovedesc rolul jucat de aceştia în forțarea radioactivă a climei. În deceniile anterioare, atenţia s-a concentrat exclusiv pe gazele responsabile pentru efectul de seră şi aşa-numita gaură de ozon, fapt ce a condus comunitatea ştiinţifică sa ia poziţie pentru a sensibiliza populaţia şi instituţiile de necesitatea de a controla emisiile. Fotometria solară la nivelul solului oferă o rezoluţie bună temporala, dar limitată la orele de zi şi de cer senin. O a doua metodă de măsură la nivelul solului este tehnica LIDAR. Caracteristicile sale, în comun cu aceste tehnici, sunt o rezoluţie temporală bună şi o reprezentare geografică relativ mică. Avantajul principal este capacitatea de a cunoaşte în detaliu acest profil de concentrare a aerosolilor. Ca şi fotometria solara, este o tehnică non-intruzivă. Ocazional, mijloacele de măsurare la nivelul solului pot fi instalate în platforme aeriene şi permit studii mai detaliate cu privire la caracteristicile pe verticală ale atmosferei.

Cuvinte cheie. aerosol, Lidar, fotometru solar, teledecție

1. INTRODUCTION

The aerosol is defined as a colloidal suspension of solid or liquid particles in a gas. When we speak of atmospheric aerosol we refer to those particles (solid or liquid state) that remain suspended in the air and are carried by this in its movement. Not included in this definition clouds whose droplets are composed almost entirely of water.

The aerosol particles are an important constituent of the atmosphere, which interacts directly with solar and terrestrial radiation, affecting the radiative balance. This interaction can be also indirectly, when certain types of aerosols, acting as condensation nuclei, activating the process of formation of water droplets or ice crystals. The radiative properties and dynamics of the clouds thus formed will depend on both the properties of the activated aerosols. For example, an abnormally large population of small hygroscopic aerosols in the presence of high humidity could trigger the formation of a cloud with a much larger number of drops than expected.

Aerosols, solid or liquid particles suspended in the atmosphere with the exception of cloud droplets, have, in particular, a role in climate change and in our perception of air quality and human health. These particles affect the climate significantly altering the radiative balance of the planet. They act, in effect, in two distinct ways, by absorbing and scattering solar radiation, a portion of the energy is scattered back to space and distributed in the atmospheric column (direct effect) but also by changing the cloud optical properties following a change of their microphysical properties (indirect effect) [1][7].

Aerosols are more difficult to characterize than the atmospheric gases due to their complex chemical composition and their wide range of sizes (from several nanometers to several micrometers). These characteristics are related to their very different origins. Indeed, these particles have two modes of formation. They may come from primary sources, that is to say directly emitted into the atmosphere as particulates (ash, sea spray, desert dust, industrial dust) or secondary sources from gas-phase to particle phase (sulfates, organic compounds, etc.).

Lidar technique is very useful in atmospheric research because it provides information on various atmospheric parameters with high spatial and temporal resolution. Sunphotometers and other passive remote sensors are able to provide information on the aerosol physical and optical properties, but these column-integrated methodologies do not provide any information on vertical structure. For this reason, Lidars are increasingly used to characterize the atmosphere, particularly in terms of vertical resolution.

The sunphotometer measure the intensity of the Sun's light, when pointed directly at the Sun, the radiation from the Sun decease proportionaly with the quantity of aerosols and gases between the Sun and the instrument.

2. METHODOLOGY

For the pourpose of this article we have used measurements from a four channel Lidar and a 8 filter Cimel CE318 sunphotometer, bouth instruments are situated in Mechanical Faculty from Politehnica University. The data from the Cimel instrument are transferred in the AERONET network.

Sun photometer measured solar radiance, then could be calculated the total water vapor and ozone column and from that the aerosol properties can be determined using a combination of spectral filters. The instrument consists of an optical head, an electronics box that contains two microprocessors for real-time operating data acquisition and control, and a robot with two motors provide motion in two planes: asimutal and zenith.

The radiometer makes two basic measurements, either direct sun or sky, both within several programmed sequences. The direct sun measurements are made in eight spectral bands, at wavelengths of 340, 380, 440, 500, 670, 870, 940 and 1020 nm that are located in a filter wheel which is rotated by a direct drive stepping motor. The 940 nm channel is used for column water abundance determination. Optical depth is calculated from spectral extinction of direct beam radiation at each wavelength based on the Beer-Bouguer Law. Attenuation due to Rayleigh scatter, and absorption by ozone, and gaseous pollutants is estimated and removed to isolate the aerosol optical depth or thickness (AOD) [2].

In addition to the direct solar irradiance measurements that are made with a field of view of 1.2 degrees, these instruments measure the sky radiance in four spectral bands (440, 670, 870 and 1020 nm. Sky radiance measurements are inverted with the Dubovik and Nakajima inversions to provide aerosol properties of size distribution and phase function over the particle size range of 0.1 to 5 um [2].

LIDAR system use light waves generated by a pulsed laser system (electromagnetic energy generated by lasers is scattered by molecules atmospheric gas and particulate matter). LIDAR technique is an active method because it uses an artificial light source to determine the atmospheric parameters, compared with passive methods using light emission derived from natural sources (sun, moon) or thermal emission. A LIDAR system emits a laser radiation that interacts with the environment or the studied subject. Part of this radiation is scattered back to the LIDAR and is captured by the LIDAR receiver's being used to determine some properties of the environment in which to spread radiation or the object that it has spread. Any LIDAR system includes, in principle, a laser source, a receiver that is based on a telescope and a signal acquisition system, Figure 1 presents the configuration of the Timisoara system. The laser is one of the basic components of a LIDAR system [3].

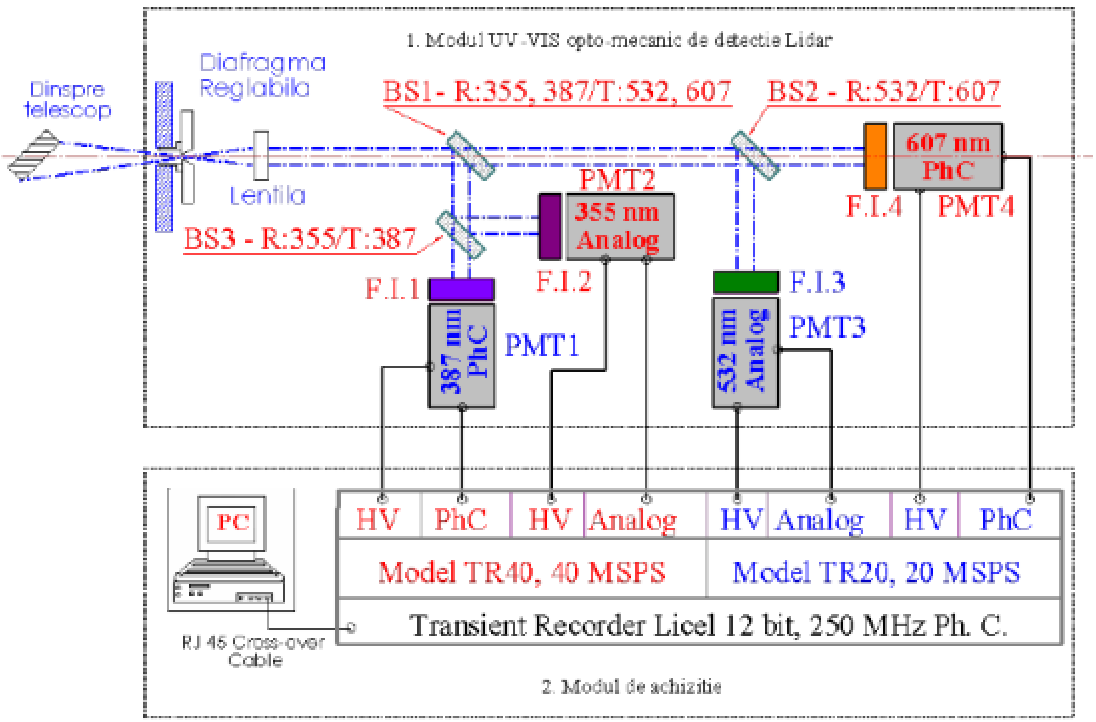

Figure 1. *Timisoara Lidar configuration*

3. RESULTS AND DISCUSSION

The optical thickness is the simplest optical property to characterize the aerosol loading in the atmosphere [4]. Represents the extinction due to the sum of dispersion and absorption spectrum of the particles, normalized in the vertical or atmospheric column. According to Mie theory, the extinction optical thickness of aerosols in the column can be obtained as the sum of the extinction of the particles:

$$AOT(\lambda, m) = \int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{ext}[x, m] \frac{n(r)}{r} dr$$

where $Q_{ext}[x, m]$ is the factor of Mie extinction efficiency of a particle with r radius and refractive index m that interact with a wave of λ wavelength, such that $x = \frac{2\pi r}{\lambda}$.

The scattering cross section of a single particle will be:

$$\sigma_{ext}[x, m] = \pi r^2 Q_{ext}[x, m]$$

represents the extinction of the incident radiation λ by a particle of r radius and m index.

In this study, we will use measurements from two days, 26 and 27 April 2011. From the Figure 2 we can observe that in the studied days optical thickness had big values, specially at small wavelengths (340nm-675nm). From this we can conclude that much of the aerosol particles are of small size, this can be also due to local traffic, industry and construction.

By analyzing Figures 3 and 4 we can observe clearly high AOT values for all wavelengths, but also episodic increases throughout the day, especially around the morning hours.

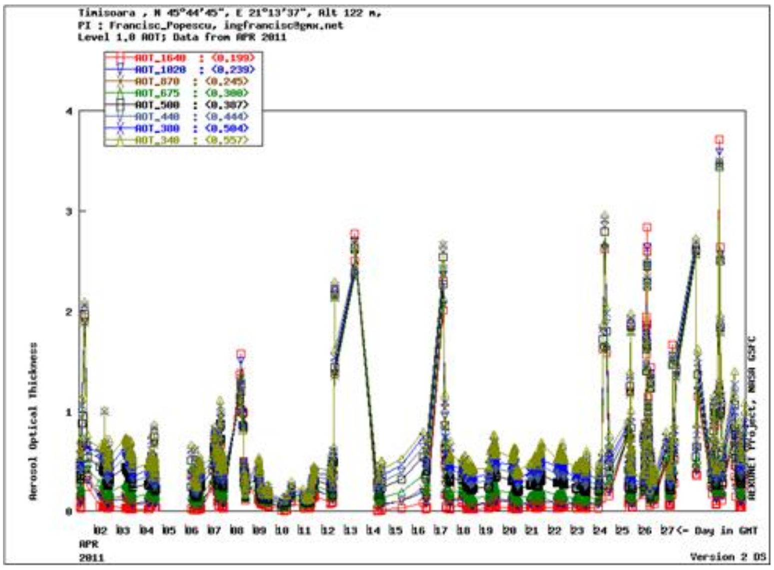

Figure 2. *Aerosol Optical Depth (AOD) for full 2011 April month [2]*

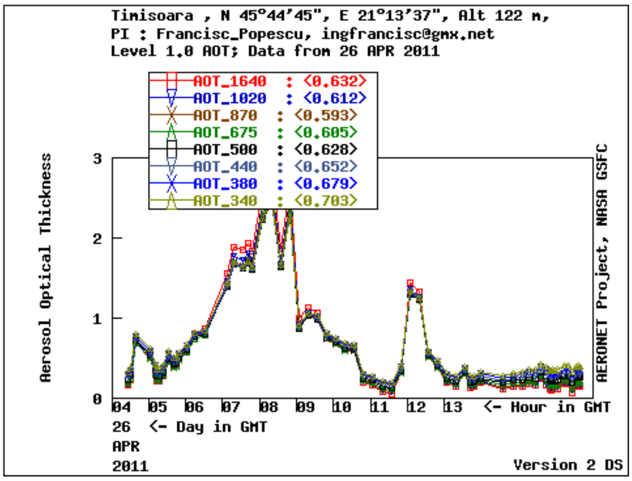

Figure 3. *Aerosol Optical Depth (AOD) from 26 of April 2011 [2]*

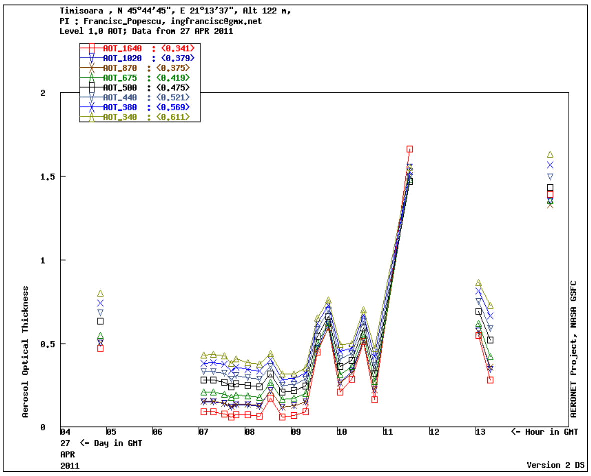

Figure 4. *Aerosol Optical Depth (AOD) from 26 of April 2011 [2]*

In Figures 5 and 6 is represented the Range Corrected Signal (RCS) from the two dates mentioned above. The planetary boundary layer can be observed at approximately 2 km, but also a very well defined layer at 4 km. In 26 of April 2011 the layer located at 4 km altitude is thin but in the next day is much visible and also has a little increase in height. The interval 7-11 km has an intense activity, with two large layers of aerosols, integrated in clouds.

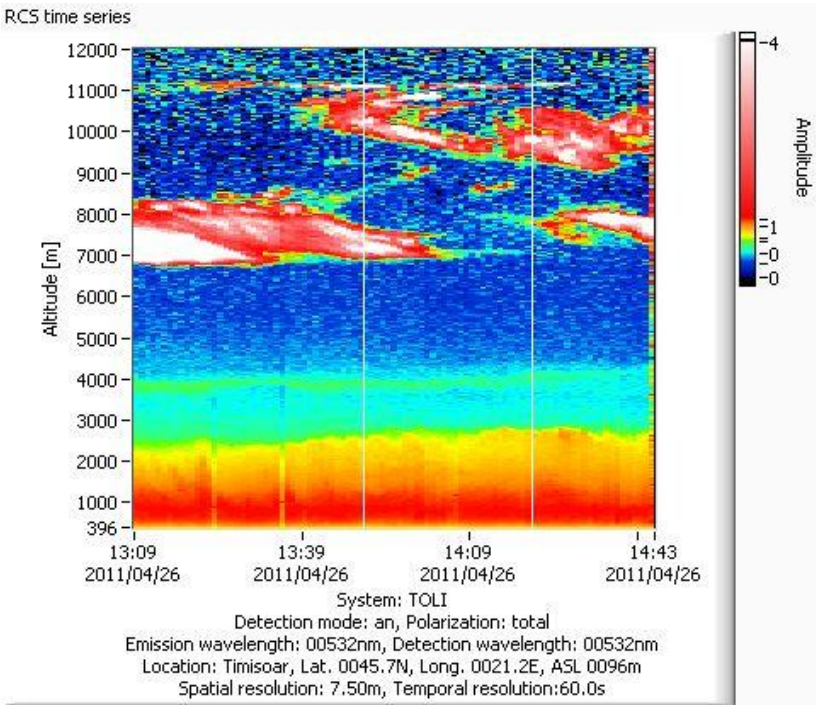

Figure 5. *RCS signal from LIDAR data generated by means of the Timisoara LIDAR, for 26.04.2011 episode, at UPT location.*

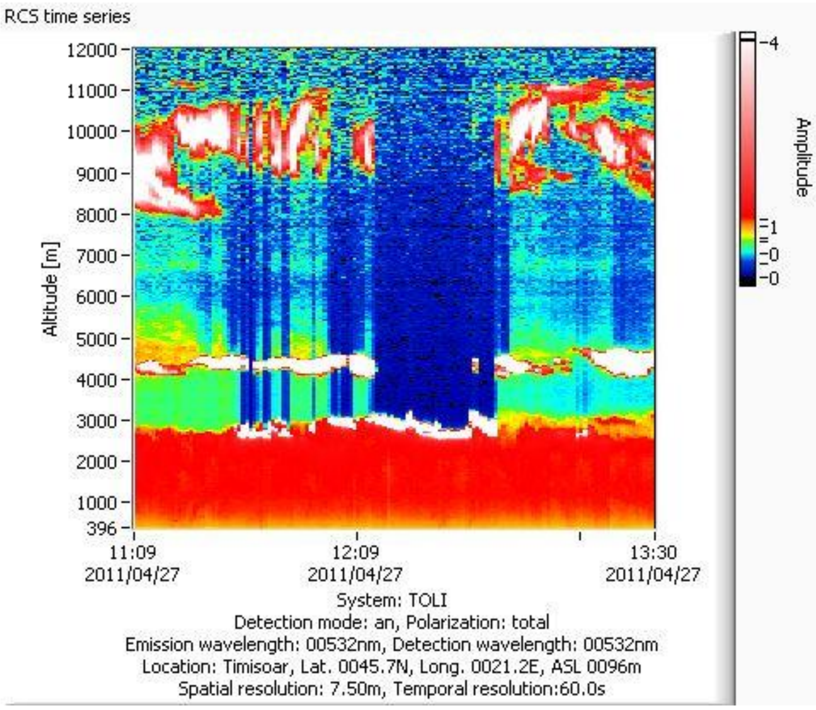

Figure 6. *RCS signal from LIDAR data generated by means of the Timisoara LIDAR, for 27.04.2011 episode, at UPT location.*

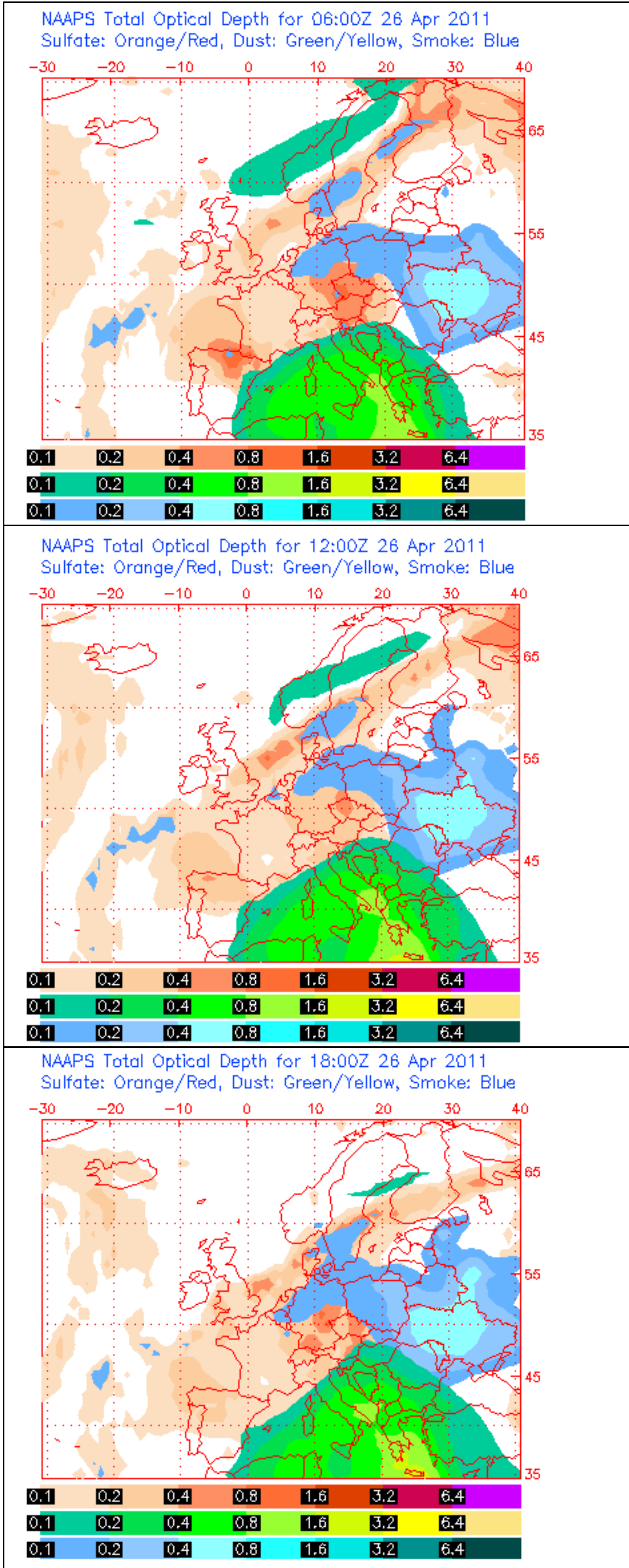

Figure 7. *NAAPS/TOMS measurements (Navy Aerosol Analysis and Prediction System) from 26 April 2011 obtained from satellite – different time of day*

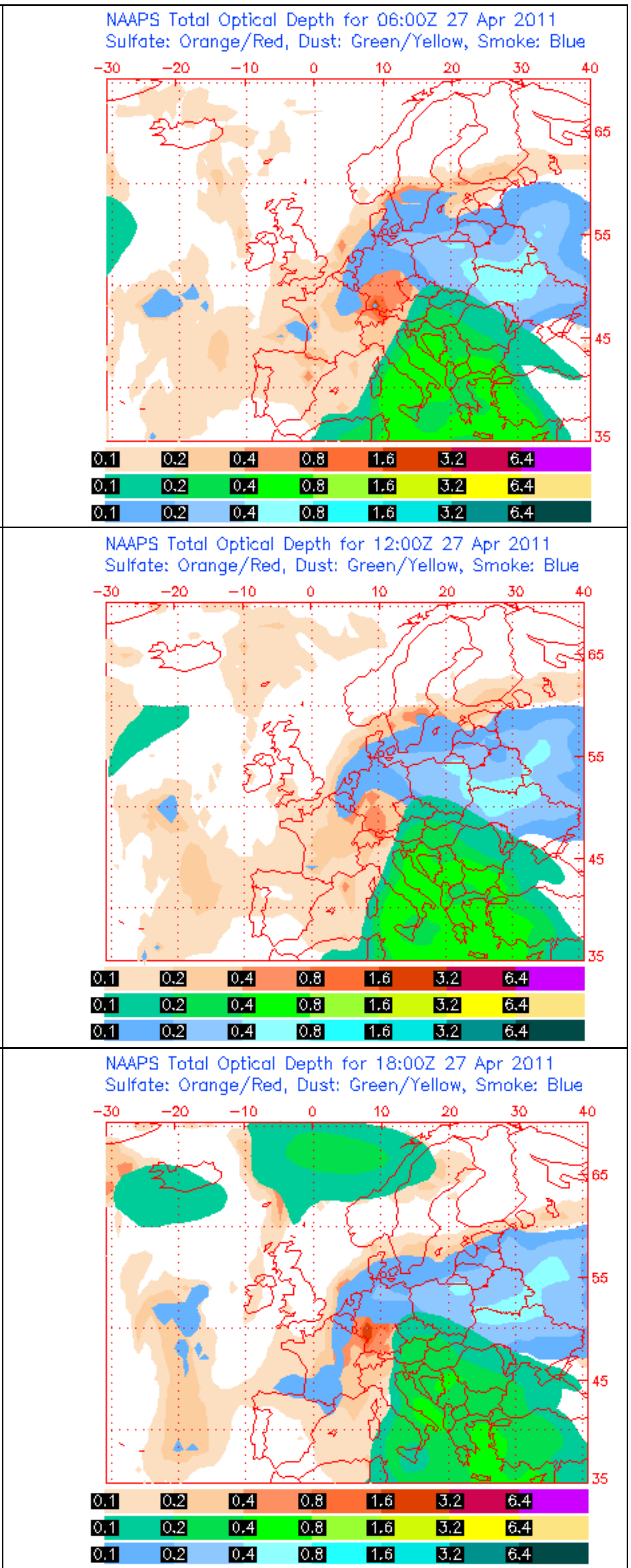

Figure 8. *NAAPS/TOMS measurements (Navy Aerosol Analysis and Prediction System) from 27 April 2011 obtained from satellite – different time of day*

The information provided by both instruments, sunphotometer and lidar, are confirmed by satellite images, in which can be clearly seen the layer of dust that reaches the Timisoara region, at around 12:00 UTC in 26 of April 2011 and cover almost all Romania in the next day. The satellite image from 27 April we can see that over the interest area a layer of smoke make his presence felt (Figure 7 and 8).

4. CONCLUSION

For a good aerosol investigation, it is necessary to have information from different instruments, in-point measurements that characterize the air near the ground and vertical profiling to know the vertical distribution of aerosol layers. The sunphotometer give us concludent information regarding the aerosol size distribution and also different optical parameters, necessary to characterize the aerosol and also to find the responsible source. Vertical profiling with the Lidar provides us with information about the vertical distribution of aerosols and very important the altitude of the layers. This information can be introduced in the trajectory models to determine origin of aerosols.

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